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Yield Performance of Soybean (*Glycine max* (L.) Merrill) Genotypes under Rust Infestation Field

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Abstract:
Soybean is an important cash and food crop cultivated throughout the tropics and sub-tropics. In Ghana, the crop is mostly cultivated in all regions of the country; however major production areas are the three northern regions. Soybean yields in Sub-Saharan Africa can be affected by a numerous constraints. This study was conducted to find the yields potentials of genotypes under rust infestation field caused by Phakopsora pachyrhizi (H. Sydow and Sydow), an obligate biotrophic fungus. Soybean genotypes used were thirty four, consisting of 32 breeding lines and two local varieties. Grain yield (t/ha) of the genotypes did vary significantly ($p < 0.05$). The yield potential of the genotypes evaluated ranged from 0.9 - 2.6 t/ha with the mean yield as 1.62 t/ha with lowest yields recorded by genotypes TGx1909-3F, SIT-M TGx1990-67F, SIT-M TGx1990-97F, SIT-M TGx1990-45F; and the highest by genotypes SIT-M TGx1989-45F.

Keywords: *soybean, rust, yield*

1. Introduction

Soybean (*Glycine max* (L.) Merrill) belongs to the family Leguminosae, in the subfamily Papilionideae. It helps in soil conservation by adding Nitrogen to the soil (Jaiswal *et al*., 2011). The crop provides high quality protein and oil for many resource poor inhabitants in Sub-Saharan Africa countries. In Ghana, soybean is cultivated mainly in the Upper East, Upper West, Northern, Central and Volta regions. The largest production occurs in Northern region of Ghana, which lies within the Guinea savanna and Sahel agro-ecological zones.

Yields of soybeans have generally been reported to be low in developing countries compared to developed countries due to many factors including diseases and drought. In Ghana, Ministry of Food and Agriculture (MoFA) (2011) indicated the average yield potential of soybean as 1.9 t/ha. Among the diseases, soybean rust (SBR) caused by *Phakopsora pachyrhizi* (H. Sydow and Sydow) has the greatest impact on soybean yield which may cause more than 75 % yield losses (Yorinori *et al*., 2005; Brink and Betay, 2006). Because most soybean farmers in Ghana are relatively poor, they do not use any form of fungicide to control rust disease. Therefore, genetic resistance is an economically and strategically important means of controlling soybean rust disease (Arias *et al*., 2008). However, report indicates that disease resistance in soybeans is mostly associated with low yield, bad pod formation, low nodule count and late maturity making breeding for rust resistance difficult (Yang *et al*., 1991).Genotypes that are tolerant to rust are very useful to farmers in order to maximise profit. Tolerant varieties could also serve as good parental sources for groundnut improvement programmes.

Therefore, this study was carried out to evaluate the yields of 34 soybean genotypes / varieties under rust infection in a soybean field labelled as a 'hot spot' for rust disease.

2. Materials and Method

2.1. Genetic Materials

Thirty-four (34) soybean genotypes/varieties used for the study is presented in Table 1.

Genotypes/Varieties	Source/Institution*	Country
TGx1909-3F	IITA	Nigeria
SIT-M TGx1990-67F	IITA	Nigeria
SIT-E TGx1987-11F	IITA	Nigeria
SIT-E TGx1988-3F	IITA	Nigeria
TGx1903-7F	IITA	Nigeria
SIT-E TGx1987-86F	IITA	Nigeria
SIT-M TGx1990-45F	IITA	Nigeria
NANGBAAR	CSIR-CRI	Ghana
SIT-E TGx1990-3F	IITA	Nigeria
SIT-E TGx1990-15F	IITA	Nigeria
SIT-E TGx1987-10F	IITA	Nigeria
SIT-E TGx1989-19F	IITA	Nigeria
SIT-M TGX1904-6F	IITA	Nigeria
SIT-E TGx1989-4F	IITA	Nigeria
SIT-M TGx1989-46F	IITA	Nigeria
SIT-E TGx1988-5F	IITA	Nigeria
ANIDASO	CSIR-CRI	Ghana
SIT-M TGx1987-91F	IITA	Nigeria
SIT-M TGx1989-42F	IITA	Nigeria
SIT-M TGx1987-14F	IITA	Nigeria
SIT-E TGx1740-2F	IITA	Nigeria
SIT-E TGx1989-21F	IITA	Nigeria
SIT-E TGx1987-62F	IITA	Nigeria
SIT-E TGx1990-97F	IITA	Nigeria
SIT-M TGx1989-45F	IITA	Nigeria
SIT-E TGx1989-20F	IITA	Nigeria
SIT-E TGx1990-2F	IITA	Nigeria
SIT-M TGx1448-2E	IITA	Nigeria
SIT-E TGX1835-10E	IITA	Nigeria
SIT-M TGx1987-96F	IITA	Nigeria
SIT-M TGx1987-40F	IITA	Nigeria
SIT- E TGx1990-8F	IITA	Nigeria
SIT-E TGx1990-5F	IITA	Nigeria
SIT-M TGx1440-1E	IITA	Nigeria

Table 1: Soybean genotypes/varieties and their sources used for the study
**IITA: International Institute of Tropical Agriculture*
CSIR-CRI: Council for Scientific and Industrial Research - Crop Research Institute

2.2. Experimental Site and Design

The experiment was conducted at Tampola, Navrongo in the Kassena Nankana District of the Upper East Region of Ghana. The area is located in the Sudan Savannah Agro-ecological Zone which experiences a unimodal rainfall pattern. The annual rainfall, temperature, relative humidity, wind speed, sunshine hours and solar radiation of the area are 885 mm, 28.6°C, 54%, 81 km day-1, 7.9 h and 20.4 M J m-2day-1, respectively (Ghana Meteorological Agency, 2013). The research work was carried out between July and November, 2014.

2.3. Land Preparation, Layout, Experimental Design, and Planting

The land was not ploughed but manually slashed with cutlass in order to maintain the stability of the pathogen community. It was also not burnt for the same reason. Stumping was done with mattocks and hoes. The debris was also manually collected. Linning and pegging were done at a planting distance of 75 cm between rows and 10 cm within rows. The experimental design used was randomized complete block design (RCBD) with three replications partitioned by two alleys of 1 m each. The two central rows were the test row from which data was taken. Each plot had four rows which was four meters long. Three seeds were planted per hill.

2.4. Soil Sampling and Analysis

Five soil cores were taken at the depths of 20 cm using a soil augur from each replication and bulked to obtain three samples. The soil samples were air-dried and sieved using 2 mm mesh sieve to remove broken sticks and other debris before the following parameters below were determined.

2.4.1. Organic Carbon
The Walkley-Black wet combustion procedure (Nelson and Sommers, 1982) was used to determine organic carbon.

2.4.2. Organic Matter
Percent organic carbon was multiplied by 1.724 (Van Bemmelen factor) to obtain percent organic matter (Nelson and Sommers, 1982).

2.4.3. Soil pH
This was measured in 1:2.5 soil to water suspension by the use of a glass Electrocalomel electrode (Mclean, 1962) pH metre.

2.4.4. Total Nitrogen
The Macro Kjeldahl method described by Bremmer and Mulvaney (1982) was used. A 10 g soil sample (< 2 mm in size) was digested with a mixture of 100 g potassium sulphate, 10 g copper sulphate and 1 g Selenium with 30 ml of concentrated sulphuric acid. This was followed by distillation with 10 ml boric acid (4 %) and four drops of indicator and 15 ml of 40 % NaOH. It was then titrated with Ammonium sulphate solution. Based on the relation that 14 g of nitrogen is contained in one equivalent weight of NH_3, the percentage of nitrogen in the soil was calculated as follows:
Total N in the sample = 14 (A-B) x N x 100
1000 x W
Where,
A = Volume of standard acid used in the titration,
B = Volume of standard acid used in blank titration,
N = Normality of the standard acid, and
W = Weight of soil sample used. 39

2.4.5. Available Phosphorous
The Bray-1 test method was used for the determination of phosphorus with dilute acid fluoride as the extractant (Jackson, 1958).

2.4.6. Exchangeable Bases (Ca, Mg, K, Na)
The exchangeable base cations were extracted using ammonium acetate at pH of 7.0. Calcium and Magnesium were determined using the EDTA titration method (Moss, 1961) while potassium and sodium were determined using the flame photometer.

2.5. Agronomic Characteristics of Soybean Genotypes

2.5.1. Days to 50 % Flowering
This was recorded as a number of days after sowing until 50 % of the plants had one or more flowers.

2.5.2. Nodule Count at 50 % Flowering
At 50 % flowering, five plants were carefully dug from both ends of the two rows on each plot. The roots of the plants were carefully dug out, put in polythene bags, together with detached nodules collected from the soil. The roots were then put in a 1 mm mesh sieve and washed under running tap water to remove adhered soil. The nodules were gently removed, washed and counted.

2.5.3. Plant Height at Harvest
The heights (cm) of the plants were taken at maturity from the ground to the tip of the main stem for five sampled plants. This was done with the use of a rule. The average plant height (cm) was calculated for each treatment.

2.5.4. Days to Maturity
It was recorded as the date when 95 % of the pods had ripened, as indicated by their mature pod colour by changing from yellow to tan or grey.

2.5.5. Seeds per 100 pods
One hundred pods were sampled and their seeds counted.

2.5.6. One Thousand (1000) seed weight
The 1000 seed weight was determined by counting 1000 seeds from the threshed and oven dried at 60 °C for 48 h for each plot and their weight determined in grammes (g) using an electronic scale.

2.5.7. Grain Yield (tonnes per hectare)
Grain yield per hectare was determined by threshing the harvested plants from the two central rows of each plot. These were put in labelled envelopes and oven dried at 60 °C for 48 hrs to a constant weight, and then weighed. The resulting weights, in grammes (g) were then scaled up to tonnes per hectare to obtain the average grain yield per hectare (Okogun *et al*., 2005).

3. Data Analysis

Data collected were analysed, using Statistics 9.0 statistical package. Analysis of Variance (ANOVA) table was computed and treatment differences were compared using the Least Significant Difference (LSD) procedure at 5 % level of probability.

4. Results

4.1. Soil Analysis of Experimental Site

The percentages of organic carbon, organic matter and total nitrogen were 0.48, 0.83 and 0.07 respectively. The exchangeable cations were recorded as 0.21, 2.6 and 0.80 Cmol/kg potassium, calcium and magnesium respectively. The value for available phosphorus was 20.22 ppm. The soil pH was 6.16 which suggested an extremely weak acid soil condition. The properties of the soil used are shown in

Soil properties		Values
% Organic carbon		0.48
% Organic matter		0.83
% Total nitrogen		0.07
Exchangeable Cations Cmol/kg	Potassium	0.21
	Sodium	0.22
	Calcium	2.60
	Magnesium	0.80
Available phosphorus (ppm)		20.22
pH		6.16

Table 2

4.2. Agronomic Characteristics

4.2.1. Nodule Count at 50 % Flowering and Plant Height at Harvest

There were significant differences ($p < 0.05$) in nodule count at 50 % flowering and the plant height among the genotypes as shown in Table 3. Genotypes SIT-M TGx1987-14F and SIT-E TGx1988-5F had 36 nodule counts per plant and were significantly different compared to the other thirty two genotypes. Genotype SIT-E TGx1987 96F recorded the highest height (84.7 cm) that was significantly different ($p < 0.05$) from the lowest height (38.0 cm) recorded by genotype SIT-E TGx1987-11F.

Soybean genotypes	Number of Nodules	Plant height (cm)
SIT-E TGx1988-3F	5	72.3
TGx1903-7F	18	49.1
NANGBAAR	26	42.6
SIT-E TGx1990-3F	21	43.5
SIT-E TGx1990-15F	0	51.3
SIT-E TGx1987-10F	24	54.8
SIT-E TGx1989-19F	15	53.4
SIT-M TGX1904-6F	27	41.9
SIT-E TGx1989-4F	16	40.7
SIT-M TGx1989-46F	2	56.1
SIT-E TGx1988-5F	36	52.1
ANIDASO	24	61.2
SIT-M TGx1987-91F	13	53.2
SIT-M TGx1989-42F	30	52.5
SIT-M TGx1987-14F	36	60.4
SIT-E TGx1989-21F	27	78.1
SIT-E TGx1987-62F	9	60.3
SIT-M TGx1989-45F	23	53.7
SIT-E TGx1990-2F	0	42.3
SIT-E TGx1835- 10E	25	60.8
SIT-M TGx1987-40F	28	82.7
SIT- E TGx1990-8F	16	50.0
SIT-E TGx1990-5F	22	57.4
SIT-M TGx1440-1E	8	60.4
TGx1909-3F	15	40.0
SIT-M TGx1990-67F	4	50.3
SIT-E TGx1987-11F	11	38.0

SIT-E TGx1987-86F	21	42.3
SIT-M TGx1990-45F	11	50.0
SIT-E TGx1740-2F	2	59.3
SIT-M TGx1990-97F	17	52.7
SIT-E TGx1989-20F	3	42.3
SIT-E TGx1448-2E	24	63.3
SIT-E TGx1987-96F	16	84.7
Mean	16.9	54.5
CV (%)	18.5	6.8
LSD (P < 0.05)	5.0	6.0

Table 3: Nodule count at 50 % flowering and plant height at harvest of soybean genotypes

4.2.2. Days to 50 % Flowering and Days to Maturity

The soybean genotypes varied significantly ($p < 0.05$) to days to 50 % flowering and days to maturity (Table 4). Genotype SIT-M TGx1987-40F took maximum days (52) and the minimum (40 days) were genotypes SIT-M TGx1990-97F and SIT-E TGx1989-20F for days to 50 % flowering. The maturity days of the genotypes varied from 84 (SIT-E TGx1987-10F and SIT-E TGx1990-2F) to 103 (ANIDASO) days.

Soybean genotypes	**Days to 50 % flowering**	**Days to maturity**
SIT-E TGx1988-3F	43	88
TGx1903-7F	43	95
NANGBAAR	48	89
SIT-E TGx1990-3F	41	86
SIT-E TGx1990-15F	41	89
SIT-E TGx1987-10F	43	84
SIT-E TGx1989-19F	41	90
SIT-M TGX1904-6F	40	92
SIT-E TGx1989-4F	42	90
SIT-M TGx1989-46F	47	98
SIT-E TGx1988-5F	41	87
ANIDASO	50	103
SIT-M TGx1987-91F	46	95
SIT-M TGx1989-42F	46	95
SIT-M TGx1987-14F	44	96
SIT-E TGx1989-21F	42	86
SIT-E TGx1987-62F	48	90
SIT-M TGx1989-45F	46	98
SIT-E TGx1990-2F	42	84
SIT-E TGx1835- 10E	42	85
SIT-M TGx1987-40F	52	96
SIT- E TGx1990-8F	42	91
SIT-E TGx1990-5F	41	87
SIT-M TGx1440-1E	45	101
TGx1909-3F	41	88
SIT-M TGx1990-67F	42	92
SIT-E TGx1987-11F	42	86
SIT-E TGx1987-86F	45	90
SIT-M TGx1990-45F	46	100
SIT-E TGx1740-2F	42	87
SIT-M TGx1990-97F	40	90
SIT-E TGx1989-20F	40	88
SIT-E TGx1448-2E	45	100
SIT-E TGx1987-96F	51	97
Mean	44.8	91.5
CV (%)	2.7	1.0
LSD (P < 0.05)	1.9	1.5

Table 4: Days to 50 % flowering and maturity of soybean genotypes

4.3. Yield and Yields Components of Soybean Genotypes

4.3.1. Seeds per 100 Pods of Soybean Genotypes

Table 5 gives the results of number of seeds per 100 pods. There were significant differences ($p < 0.05$) in number of seeds per 100 pods among the genotypes. Genotypes SIT-M TGx1989-45F had the highest number of seed per 100 pods (257), however, this was not significantly different ($p > 0.05$) from genotypes SIT-E TGx1990-2F (248 seeds), SIT-E TGx1987-10F (246 seeds) but, differed greatly from genotype SIT-M TGx1990-45F which produced the least number (97 seeds).

4.3.2. 1000 Seeds Weight of Soybean Genotypes

Results of 1000 seeds weight of the genotypes are present in Table 5. Genotype SIT-E TGx1990-2F had 172.3 g which was different the other 33 genotypes. There was no difference in 1000 seeds weight (137.7 - 145 g) among genotypes SIT-E TGx1987-10F, SIT-E TGx1990-5F and SIT-E TGx1835-10E, however it differed from genotypes SIT-E TGx1990-8F, SIT-E TGx1989-21F, SIT-E TGx1988-5F and SIT-M TGx1904-6F which recorded similar 1000 seed weights (115.5 - 122.8 g).

4.3.3. Grain Yield of the Soybean Genotypes

Grain yield (t/ha) of the genotypes did vary significantly ($p < 0.05$) (Table 5). The yield potential of the genotypes evaluated ranged from 0.9 - 2.6 t/ha with the mean yield as 1.62 t/ha with lowest yields recorded by genotypes TGx1909-3F, SIT-M TGx1990-67F, SIT-M TGx1990-97F, SIT-M TGx1990-45F; and the highest by genotypes SIT-M TGx1989-45F.

Genotypes	Seeds/per 100 pods	1000 seeds weight (g)	Grain yield (t/ha)
SIT-E TGx1988-3F	234	133.7	2.2
TGx1903-7F	218	110.2	2.0
NANGBAAR	186	90.8	1.5
SIT-E TGx1990-3F	191	151.5	2.2
SIT-E TGx1990-15F	189	127.7	1.6
SIT-E TGx1987-10F	246	137.7	1.9
SIT-E TGx1989-19F	220	133.3	1.4
SIT-M TGX1904-6F	215	122.8	1.7
SIT-E TGx1989-4F	215	147.8	1.6
SIT-M TGx1989-46F	146	131.0	1.8
SIT-E TGx1988-5F	184	121.3	2.1
ANIDASO	206	100.2	1.7
SIT-M TGx1987-91F	234	145.2	2.4
SIT-M TGx1989-42F	213	124.3	1.3
SIT-M TGx1987-14F	126	102.7	1.3
SIT-E TGx1989-21F	190	120.3	1.9
SIT-E TGx1987-62F	206	98.0	1.8
SIT-M TGx1989-45F	257	158.7	2.6
SIT-E TGx1990-2F	248	172.3	2.1
SIT-E TGx1835- 10E	167	145.0	2.0
SIT-M TGx1987-40F	210	148.8	2.5
SIT- E TGx1990-8F	198	115.5	1.9
SIT-E TGx1990-5F	213	144.0	1.7
SIT-M TGx1440-1E	179	100.5	1.8
TGx1909-3F	106	86.0	0.9
SIT-M TGx1990-67F	98	86.3	0.9
SIT-E TGx1987-11F	107	89.3	1.1
SIT-E TGx1987-86F	112	91.7	1.2
SIT-M TGx1990-45F	97	87.3	0.9
SIT-E TGx1740-2F	104	89.2	1.0
SIT-M TGx1990-97F	103	87.8	0.9
SIT-E TGx1989-20F	137	91.3	1.2
SIT-E TGx1448-2E	113	90.3	1.0
SIT-E TGx1987-96F	113	91.3	1.1
Grand Mean	177.0	116.9	1.6
CV (%)	5.9	4.5	9.4
LSD ($P < 0.05$)	17.0	8.5	0.3

Table 5: Seeds per 100 pods, 1000 seed weight and grain yield of soybean genotypes

5. Discussion

5.1. Soil Analysis

According to Adepetu and Corey (1976), organic matter value of 0.8 % is within the critical value of 0.5 - 4.0 % but total nitrogen value of 0.07 % is less than the its critical value of 0.15 %. The soil was high in the exchangeable cations based on the critical levels of 0.21, 2.6 and 0.80 cmol/kg potassium, calcium and magnesium, respectively (Akinrinde and Obigbesan, 2000). The available phosphorus value of 20.22 ppm is above 12 ppm (Bray-1 test) and a pH value of 6.16 is within the recommended value of 5.5 - 7.0 for soybean production (Ferguson et al., 2006). The properties of the soil made the planting site relatively good for soybean production, since the most of the soil test results are within the standards for its production (Ferguson et al., 2006; Akinrinde and Obigbesan, 2000; and Adepetu and Corey, 1976).

5.2. Agronomic (yield) Components

A comparison of seed yield and yield contributing traits (seeds per 100 pods, 1000 seeds weight) showed that there were significant differences among the genotypes evaluated (Table 5). Genotype SIT-E TGx1989-45F recorded the highest grain yield (2.6 t/ha), highest number of seeds (257) per 100 pods and second highest 1000 seed weight. This indicated that, yield is a function of individual seed weight and number of seed per pods when the crop matures.

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